# FERTILITY STUDIES OF THREE KANSAS SOILS, i.e. LADYSMITH, GEARY AND SARPY WITH SPECIAL REFERENCE TO CATION EXCHANGE AND CLAY MINERALS

by

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Hyderabad, India, 1949

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A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

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# INTRODUCTION AND REVIEW OF LITERATURE

This study was conducted mainly to study the fertility status of the three soil series of Kansas. The soil series are Ladysmith, Geary and Sarpy. The approach was more of a physico-chemical nature than of pure chemical or biological nature. Not many of these soils are characterized in this way. Hence, it was expected that this paper should provide basic information regarding the characteristics of these soils in general and cation exchange phenomena in particular.

Kelley (15) in his book "Cation Exchange in Soils" has reviewed the historical development of cation exchange. According to him, H. S. Thompson, in 1850 was the first scientist who studied cation exchange phenomena systematically. However, there were two more scientists who worked independently and published their work in the same year 1850, as Thompson did. These two scientists were—J. F. Way, an Englishman who worked at Rothamsted Experiment Station and a Swede, G. Forschamer who published his work in 1850. Thompson showed that when the soils were mixed with ammonia and leached with water, much of the ammonia remained in the soil. Way published his work and showed that the cation exchange phenomena in soils was due to the clay fraction and was connected with silicate compounds. Forschamer showed that when the soil was leached with sea water, $Ca^{++}$ and $Mg^{++}$ ions were released. Following the pioneering efforts of these scientists, this phenomenon was studied and further investigations were carried out by various workers in different parts of the world.

As far as soils are concerned, this phenomenon is considered to be the most important for the cation absorption of the plants. Marshall (21) regards the phenomenon of cation exchange as the second most important in nature, surpassed only by photosynthesis. Even the normal functioning of chlorophyl, in the process of photosynthesis, is dependent to a certain extent on the activity of certain metalic cations like $Mg^{++}$ which constitutes 2.7 percent of the chlorophyl content. Hence, this phenomenon in soils is the most important one and in many ways is connected with different soil reactions and is responsible for shaping the soil characteristics. Many soil reactions for instance, soil acidity and basicity, fertilizer response, reclamation of soils (both acids and alkali), nutrient absorption; weathering, shrinkage and swelling and leaching and retention of nutrients in soils, are all closely associated with cation exchange activity.

Before 1930 (22) clays were considered to be the amorphous isoelectric precipitates of the iron and aluminum hydroxides and silicic acid. According to Giesekirg (8), Pauling in 1930 using x-ray diffraction technique, showed the crystal structure of mica. Likewise according to Giesekirg (8), Gruner in 1932 using this improved technique showed the differentiation between different groups of clay minerals and finally in 1932 he determined the crystal structure of kaolinite. A year later, according to Giesekirg (9), Hofman determined the structure of montmorillonite. In 1937, the name illite was suggested by Grim for a group of minerals formerly named as hydrous mica by Hendricks and Alexander (Giesekirg, 8 and 9).

The property of cation exchange in soils is largely dependent on soil colloids, which can be conveniently divided in two groups—organic colloids and the inorganic colloids or the clay minerals (also called layer silicates). The former group is represented by the organic matter content of the soil and the latter by the clay minerals. All things being equal, cation exchange phenomena are the functions of these two components of any soil. The cation exchange capacity of a soil varies greatly with its organic matter content. Barshad (1) is of the opinion that cation exchange capacity in soils due to organic matter may be from a minimum of 6.9 percent to a maximum of 50 percent, depending upon the organic matter content and its state of decomposition.

The inorganic component of the soil colloids is believed by various investigations (14, 16, 17 and 26) to be the most active of the rest. The very essence of fertility is often attached to the clay minerals. These minerals have the ability to renew the available nutrient supplies of soils. In other words the commonly known term 'soil fertility' is a manifestation of the functions of soil colloids as a whole and of the clay minerals in particular. So in fertility studies of soils, not only organic matter, but also the type of clay minerals and their content are of importance.

Toth (29) stated the dominant clay minerals in Great Soil Groups of the world. According to him, in Chestnut and Prairie soils montmorillonite is the dominant mineral while in Chernozems montmorillonite and illite minerals are dominant and in Podzols illite is present as the dominant one. Kelley, et al (18) mentioned that Ross and Shannon who had showed that the dominant and the most important constituent of certain types of bentonites was the micaceous crystalline mineral, montmorillonite.

Grim (10) stated the cation exchange capacity of different clay minerals. According to him, montmorillonite has a cation exchange capacity 80-150 me. per 100 g. and kaolinite 3-15 me. per 100 g. of mineral.

Kelley et al (18) working with Prairie type of soils of California, found that purified bentonites had the base exchange capacity of 105 to 110 me. per 100 g. of dry material. They used two more purified bentonites from other sources and determined the cation exchange capacities of each. One had a capacity of about 55 me. per 100 g. of dry material while the other ranged from 82 to 88 me. per 100 g.

In view of the interrelationship of cation exchange reactions and various other soil phenomena, more knowledge of the following characteristics of the soils was needed to study their fertility aspect as a whole:

a) mechanical analyses
b) organic matter contents
c) species of clay minerals
d) exchangeable cations
e) exchange capacities
f) pH values of the soil
g) base saturation percentages

## MATERIALS AND METHODS

Three soils were selected for this study. These are Ladysmith silty clay loam; Geary clay loam; and Sarpy fine sandy loam. A brief description of each is given below.

### Ladysmith Soil Series[1]

This series includes dark colored, moderately fine textured, strongly developed Planosol-chernozems, developed in nearly level to slightly undulating Wisconsin loess. Ladysmith soils have a dark A horizon and a gray and clayey B horizon. The change from A to B horizon is not abrupt.

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[1] O. W. Bidwell, Geary County, Kansas Soil Survey Report, in press.

Typical Profile.

Location;-One hundred fifty feet south of west quarter corner, section 27, T13S, R8E.

Profile;-$A_{11}$ 0-5" Dark gray (10 YR4/1 dry) silty clay loam. Very dark gray (10 YR 2-5/1 moist).

Moderately fine and medium granular structure; slightly hard, firm; pH 5·6; clear boundary; 3-6" thick; roots abundant.

$A_{12}$ 5-8" Dark gray (10 YR 4/1 dry) silty clay loam. Very dark gray (10 YR 2-5/1 moist).

Moderately fine and medium, subangular blocky structure; slightly hard, firm; pH 5·4; clear boundary; abundant roots; 0-4" thick.

$B_{21}$ 8-14" Gray (10 YR 5/1 dry) clay, very dark gray (10 YR 2-5/1 moist); moderately coarse prismatic structure breaking to moderately medium blocky structure; very hard, very firm; pH 5·5; clear boundary; 5-10" thick.

$B_{22}$ 18-27" Gray and grayish brown (10 YR 5/1, 5/2 dry) clay. Very dark gray (10 YR 3/1 moist); few yellowish red (5 YR 5/6 dry) fine distinct mottles; moderate medium blocky structure; very hard; very firm; pH 7·2; clear boundary; 5-10" thick.

$B_{3Ca}$ 27-34" Light brownish gray and pale brown (10 YR 6/2, 6/3 dry) clay; grayish brown (10 YR 5/2 moist) few yellowish red (5 YR 5/6 dry) fine distinct mottles;

weak blocky structure, very hard, very firm; many black shot and calcium carbonate concretions; 2pH 7·2; clear boundary; 5-10" thick.

$C_1$ 34-48" Light gray (10 YR 7/1, 7/2 dry) clay, light brownish gray (10 YR 6/2 moist); many light yellowish brown (10 YR 6/4 dry) coarse prominent mottles; hard, firm; few calcium carbonate concretions; pH 8·2; abrupt boundary; 10-24" thick.

Topography :— Nearly level to gently tabular, loess mantled erosional upland.

Drainage and Permeability:- Well drained to moderately well drained on the more level areas because of the very slow subsoil permeability. Run off is medium to rapid.

Vegetation:- Mid and tall grasses of native bluestem prairie.

Use. Well adapted to wheat. Less well adapted to sorghum and alfalfa. Lands on steep slopes are maintained as native grass pastures.

Distribution:- On the nearly level tabular uplands of southeastern Geary County and adjacent counties.

## Geary Soil Series[1]

Geary series consists of well drained moderately dark colored moderate to fine textured, reddish prairie soils, developed in reddish brown loess or loess-like materials believed to be of post Illinoian age. These soils occur in the transition belt between Chernozen and Prairie zones.

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[1] Description by O. W. Bidwell.

Typical Profile.

Location:-Nine feet south, Nine feet east of southwest corner of weather instrument area, Agronomy Farm. E½ sec. 1, T10S, R7E. Slope ½ percent, erosion slight; dry to 4 feet and slightly moist below that depth when sampled.

Soil Profile:- $A_{1p}$ 0-3" Grayish brown (10 YR 5/1-5 dry); very dark gray (10 YR 2.5/1 moist, clay loam; moderate very fine granular structure; friable and slightly hard; non-calcareous; abrupt boundary; 3-8" thick.

$A_{21}$ 3-8" Dark grayish brown (10 YR 4/1.5 dry), very dark gray (10 YR 2.5/1 moist), clay loam; moderate very fine sub-granular blocky structure; firm, hard; non-calcareous; clear boundary; 4-8" thick.

AB 8-14" Dark gray (10 YR 4/1 dry), very dark gray (10 YR 3/1 moist); silty clay loam; strong very fine sub-angular blocky structure; firm, extremely hard; non-calcareous; clear boundary; 4-8" thick.

$B_{21}$ 14-30" Grayish brown (10 YR 5/2 dry), very dark grayish brown (10 YR 3/2 moist); clay; moderate medium blocky structure; very firm, very hard; non-calcareous; clear boundary; 10-15" thick.

$B_{22}$ 30-42" Brown and dark brown (10 YR 5/3 & 4/3 dry) and dark brown (10 YR 4/3 moist); clay; weak blocky structure; very firm, very hard; non-calcareous; clear boundary; 10-15" thick.

$B_3$ 42-52" Pale brown and yellowish brown (10 YR 6/3, 5/4 dry), and (10 YR 5/3, 7·5 YR 4/4 moist); clay; many fine distinct mottles; massive structure; very firm, extremely hard; non-calcareous; clear boundary; 8-12" thick.

C 52-60" Pale brown and yellowish red (10 YR 6/3, 5 YR 4/7 dry), and (7·5 YR 5/4, 4/4 moist); clay; many fine distinct mottles; massive structure; firm, extremely hard; non-calcareous.

Topography - Nearly level to rolling relief on eroded uplands.

Drainage and Permeability;-Well drained; run-off medium; permeability moderately slow.

Native Vegetation;- Bluestem prairie consisting of little bluestem, big bluestem; indiangrass, switchgrass and sideoats grama.

Use;- Highly productive soils when cultivated occur in 30-32" rainfall belt in Kansas. They are well adapted to wheat, alfalfa, oats, grain, sorghum and corn.

Distribution;- Northcentral and northeastern Kansas and adjacent parts of Nebraska. Greatest extent along the Kansas River and its tributaries.

## Sarpy Soil Series [1]

This is a light colored, coarse textured, well drained, neutral to calcareous alluvial soil of the Republican and Kansas River Valleys. It is sandy throughout the profile. Its surface color is grayish brown and the subsoil is pale brown.

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[1] O. W. Bidwell, Geary County, Kansas Soil Survey Report, in press.

Typical Profile.

Location:-One hundred fifty feet east and 50 feet north of west quarter corner, sec. 18, T11S, R5E. Cultivated, two percent undulating slope.

A1 0-20" Grayish brown (10 YR 5/1.5 dry), to dark grayish brown (10 YR 4/2, moist); loamy fine sand; massive structure; soft, very friable; calcareous; gradual boundary; 10 + 0 20" thick.

C 20-60" Pale brown (10 YR 6/3 dry) to grayish brown (10 YR 5/2 moist); loamy fine sand; single grain structure; soft, very friable; non-calcareous.

Permeability is very rapid. Run-off is low, water table is within 8 feet of the surface. This soil is subject to periodic flooding. Fertility is moderate. Crops grown are wheat, sorghum, alfalfa, corn and oats.

## Collection and Preparation of Samples

Three soil series were sampled for fertility investigation. The soils and their location are.

| Soil Type | Location |
|---|---|
| 1. Ladysmith silty clay loam | Northeast corner; section 33, township 12 south, range 8 east. Geary Co., Kansas. |
| 2. Geary clay loam | Agronomy Farm, 9 feet south, 9 feet |

| | |
|---|---|
| | east of southwest corner of weather instrument area. East one-half, section 1, township 10 south, range 17 east, Riley Co., Kansas. |
| 3. Sarpy fine sandy loam | Ashland Agronomy Farm. Northwest quarter of the northeast quarter, section 34, township 10 south, range 7 east, Riley Co., Kansas. |

Three samples were collected from each soil representing A, B and C horizons.

Collected samples were dried under shade for a week. This air-dry sample of each soil was ground by means of a manually operated grinder and sieved through two mesh screens. Thus obtained material, "fine earth", was used for all these investigations.

## Mechanical Analysis

Mechanical analysis was made according to the method of Bouyoucos (2) and (19). Fifty g. of oven-dry soil were added to the dispersing cup and the cup was filled with distilled water within 2 inches of the top. Five ml. of normal solution of sodium hexametaphosphate were added and the soil allowed to soak. The cup was then connected to the stirring motor and the following timings were given;

Ladysmith soil samples - 15 minutes
Geary soil samples - 15 minutes
Sarpy soil samples - 10 minutes.

After the specified period, the contents of the cup were poured into the special cylinder and filled to the lower mark, keeping the hydrometer in it. Contents were once again mixed and stirred and kept on the table. Immediately the time was noted. Hydrometer readings were taken after each specified time. Readings of hydrometer were taken each at the end of 40 seconds, four minutes and two hours.

For American systems — 40 seconds and two hours.

For International systems — 4 minutes and two hours.

At the time of taking hydrometer reading, the temperature of the suspension was noted. A correction factor of 0.2 graduation on hydrometer was used for each degree above 67°F. For the U. S. Department of Agriculture particle classification, the corrected hydrometer readings at the end of 40 seconds is divided by the amount of absolute dry soil taken and multiplied by 100. This shows the percentage of material still in suspension and represents all the sand in the soil 2.0 mm to 0.05 mm. The corrected hydrometer reading is also divided by the weight of the soil taken and multiplied by 100. This gives the percentage clay ( _ .002 mm). The silt fraction (0.05 mm to 0.002 mm) is obtained by difference, i. e. by subtracting the combined percentages of sand and clay from 100.

Calculations for International system were made on the similar basis.

## Water Saturation Percent

Five hundred g. of air-dry soil were weighed and wetted with distilled water while stirring with spatula. Water was added in quantities of 5 ml. at a time and finally the paste was mixed thoroughly for about five minutes with the help of a planetary type power driven mixer. The total quantity of water added was noted for calculation of saturation percentage (31). Water was added until the paste developed a glistening surface and became a thin paste which just flowed and dripped easily down the spatula.

After the specified period of five minutes, the paste was removed from the planetary mixer and transferred in the Buechner funnel after covering the porous surface with filter paper. The Buechner funnel along with the suction flask was fixed to air evacuator and the liquid was collected up to about 25 ml. and removed for the determination of water soluble cations. The calculation of the water saturation percent was as follows:

$$\text{Saturation percent of a soil} = \frac{\text{weight of } H_2O \text{ added.}}{\text{weight of air dry soil}} \times 100.$$

The data obtained are shown on page 25. Twenty-five ml. extract obtained from this process were made to 100 ml. and used for the determination of water soluble cations.

## Organic Matter Content

This component was determined by Walkley's chromic acid method as mentioned by Jackson (13) and as outlined below:

Reagents:- 1) 1N Potassium dichromate - prepared by dissolving 49.04 g. of reagent grade $K_2Cr_2O_7$ in water and made to one liter.

2) 0.5N $FeSO_4$ - 140 g. of reagent grade $FeSO_4 \cdot 7H_2O$ added, cooled and made to one liter and standarized against 1N Potassium dichromate.

3) $H_2SO_4$ not less than 96 percent pure.

4) $H_3PO_4$ 85 percent pure. U. S. P. grade.

Procedure:- Five-tenths g. of soil was weighed and transferred into 500 ml. erlenmeyer flask. Ten ml. of 1N $K_2Cr_2O_7$ were added, directing the stream into the solution. Mixed gently, shaking by hand for one minute and left to stand for about 30 minutes. Two hundred ml. of distilled water, 10 ml. of $H_3PO_4$ and 0.2 g. of NaF were added to each flask. Back titration was carried on against 0.5N Ferrous sulfate in the presence of 0.5 ml. indicator—diphenyl amine. End point was the sudden appearance of bright green color. A blank was treated simultaneously.

Calculation:-Percent organic matter = $10\ (1-\frac{T}{S}) \times 1.34$. Where S = Reading of standardization blank. T = Sample titration reading.

## pH Determination

This measurement was made in a 1:1 soil to water paste as outlined by Jackson (13).

Twenty g. of air dried soil were placed in a 50 ml. beaker. Twenty ml. of distilled water were added and well mixed at a regular intervals of 10 minutes for one hour and the pH was measured with the glass electrode on Beckman's pH meter. The paste was well stirred just before taking the pH readings.

## Water Soluble Cations

The extract from the determination of the water saturation percentage was made to 100 ml. volume and the cations were determined by use of the Beckman flame spectrophotometer.

## Exchangeable Cations

These were determined by use of the centrifuguge and flame spectrophotometer as outlined by several workers, (5, 6, 13, 25 and 30).

Procedure:- Two g. of air-dry soil were placed in a 100 ml. centrifuge tube. Soil was suspended in 50-60 ml 1N ammonium acetate. Mechanical stirrer was used for well mixing and dispersing. Treated sample was centrifuged at 2500 rpm. for 10 minutes and supernatant liquid was saved. This whole process was repeated four additional times and the supernatant liquid was saved at the end of each centrifugation. The whole solution was evaporated to dryness over a drying pan. The left over residue was redissolved in 1N ammonium acetate and made up to 50 ml. volume.

Scale readings for the cations were read on the Beckman D. U. spectrophotometer and the concentration of each cation in solution was obtained by reference to a standard curve made from standard solutions which were treated in the same manner as were the samples.

## Cation Exchange Capacity of Soils

These determinations were made according to the methods of Jackson (13), and Rogers (27).

Procedure:- Two g. of air-dry soil were placed in 100 ml. centrifuge tube. Soil was suspended in 50 ml. of 1N $CaCl_2$ by means of mixer and centrifuged at the rate of 2500 rpm. for 10 minutes. The supernatant liquid was discarded. Soil was resuspended in 50 ml. of 1N. calcium acetate, centrifuged and supernatant liquid discarded. Again it was resuspended in

1N calcium acetate and supernated liquid was discarded. Then soil was resuspended in 50 ml. of 1N $CaCl_2$ mixed, centrifuged and supernatant liquid discarded. Then the soil was suspended in ethyl alcohol, mixed, centrifuged and supernatant liquid discarded. It was done twice and then the soil was suspended in absolute methyl alcohol, mixed and centrifuged as many times as were necessary for the removal of chloride (no test with $AgNO_3$). Finally the sample was suspended in 1N ammonium acetate, centrifuged and supernated liquid was saved. This was done five times. The final volume made up to 250 ml. for spectrophotometric analysis.

## Cation Exchange Capacity after Oxidation of Organic Matter

The method for determining the cation exchange capacity is described on page 14. The same method was followed after oxidation of organic matter. The latter was done by the $H_2O_2$ method of Jackson (13) and is briefly mentioned here.

Two g. of soil were transferred into a 250 ml. beaker with 10 ml. of $H_2O$. Five ml. of $H_2O_2$ were added. The beaker was covered with a watch glass. The sample was heated gradually and when reaction was quiet another 5 ml. of 30 percent $H_2O_2$ were added. This was done until frothing was stopped and finally 10 ml. of $H_2O_2$ were added and heated until the entire liquid was reduced to about 5 ml. The beakers were removed from the evaporating pan and the centrifugal procedure carried out.

## X-Ray Diffraction of Clays

Clay Fractioning. Procedure:- Jackson (12)

1. Twenty g. of heavy soils and 40 g. of light soils were used.
2. Removal of $CaCO_3$ was done by heating with .003 N HCL (pH= 3).
3. Organic matter was removed by $H_2O_2$ method-two 5 ml. portions and one 10 ml. portion was heated.
4. Removal of free iron oxides.

   40 ml. - 0.3 M $NaNO_3$

   5 ml. - 1.0 M $NaHCO_3$

   Heated to 80°C and 1 g. of $Na_2S_2O_4$ added and stirred for 1 minute. Heated for 15 minutes, 10 ml. of saturated NaCl were added, mixed by means of stirrer and centrifuged at 2200 rpm. for 10 minutes.
5. Boiled gently in 2 percent $Na_2CO_3$.
5. Centrifuged at 750 rpm. for 3 minutes, washed 3 times with $Na_2CO_3$ and twice with $H_2O$ and thus sand and silt were separated.
7. Separation of 2 micron to .2 micron fraction, centrifuging was done at the rate of 25,000 rpm. and 415 ml. per minute.
8. Separation of .2 micron — .08 micron fraction, centrifuging at 25,000 rpm. at 55 ml. per minute.
9. Separation of $\angle$.08 micron fraction of clay - Filtrate obtained from eighth step was flocculated with saturated solution of NaCl and flocculated material was separated by ordinary centrifuging at 2000 rpm. for 10 minutes.

Preparation of Samples for Random Powder Diffraction. Procedure:- Jackson (12).

1. Pretreatment - Aliquot containing about 50 mg. was placed in 150 ml. beaker. Fifty ml. of Na-acetate-H O A C (pH=5) were added and boiled

gently for five minutes.

2. Calcium saturation:- Aliquot containing 50 mg. was flocculated with $1\underline{N}$ $CaCl_2$ + three ml. of 10 $\underline{N}$ $CaCl_2$ and centrifugation was done at the rate of 2000 rpm. Finally samples were washed with the following solutions:

once with $1\underline{N}$ $CaCl_2$
twice with $1\underline{N}$ $Ca(CH_3COO)_2$, pH=7.7
once with $1\underline{N}$ $CaCl_2$
once with 50 percent methanol
once with 95 percent methanol
twice with acetone to remove chlorides.

3. Glycerol Solvation:- material was washed with the following reagents:-

1. twice with benzene-ethanol (10 to 1 by volume), three times with benzene-ethanol-glycerol (1000:100:4.5 by volume), once with 10 ml. benzene-ethanol (200:1 volume) and finally the fractions were suspended in benzene and allowed to dry in large watch glasses.

When the samples were dry, they were removed by scraping, gently crushed and finally capillaries were filled with clay for X-ray diffraction.

X-ray diffraction was carried out for the following ranges of fractions in each sample.

ranges - $2\mu - 0.2\mu$.
$0.2\mu - 0.08\mu$
and $\angle .08\mu$.

The d or basal spacings were calculated against cobalt target. The data are presented in the later pages.

Identification of Clay Minerals. After the samples were prepared and X-ray diffraction patterns were made, identification of clay minerals was accomplished. These identifications were made in accordance with the methods proposed by various investigators (3, 4, 10, 11, 12, 20, 28 and 32).

## EXPERIMENTAL RESULTS

Table 1. Mechanical analyses - (a) Hydrometer and corresponding temperature readings.

| Soil series and horizon | 40 seconds | | 4 minutes | | 2 hours | |
|---|---|---|---|---|---|---|
| | Hydrometer reading | Temp. °F | Hydrometer reading | Temp. °F | Hydrometer reading | Temp. °F |
| Ladysmith A | 35.0 | 87.8 | 24.0 | 87.8 | 10.0 | 84.4 |
| Ladysmith B | 40.0 | 87.6 | 33.0 | 87.4 | 21.0 | 84.4 |
| Ladysmith C | 40.0 | 87.8 | 31.0 | 87.4 | 18.0 | 84.0 |
| Geary A | 34.0 | 87.0 | 24.0 | 86.6 | 10.0 | 83.4 |
| Geary B | 40.0 | 86.4 | 30.0 | 87.0 | 17.0 | 83.4 |
| Geary C | 37.0 | 86.6 | 26.0 | 86.4 | 16.0 | 83.2 |
| Sarpy A | 16.0 | 85.8 | 3.0 | 85.6 | 0.5 | 82.8 |
| Sarpy $C_1$ | 15.0 | 86.3 | 2.0 | 85.8 | 0.0 | 83.0 |
| Sarpy $C_2$ | 21.0 | 85.2 | 3.5 | 85.0 | 0.0 | 83.0 |

Table 2. Mechanical analyses - (b) corrected hydrometer readings.

| Soil series and horizon | Corrected hydrometer readings | | |
|---|---|---|---|
| | 40 seconds | 4 minutes | 2 hours |
| Ladysmith A | 39.16 | 28.16 | 13.48 |
| Ladysmith B | 44.12 | 37.04 | 24.48 |
| Ladysmith C | 44.16 | 35.08 | 21.40 |
| Geary A | 38.00 | 27.92 | 13.28 |
| Geary B | 43.88 | 34.00 | 20.28 |
| Geary C | 40.92 | 29.88 | 19.24 |
| Sarpy A | 19.76 | 6.72 | 4.06 |
| Sarpy $C_1$ | 18.86 | 5.76 | 3.20 |
| Sarpy $C_2$ | 24.64 | 7.10 | 3.20 |

Table 3. Mechanical analysis of soils — (c) textural classification.

| Soil series and horizon | U. S. system | | | International system | | | Textural classification (U.S.D.A.) |
|---|---|---|---|---|---|---|---|
| | Sand 2.0 mm to 0.05 mm % | Silt 0.05 mm to 0.002 mm % | Clay <0.002 mm % | Sand 2.0 mm to 0.2 mm % | Silt 0.2 mm to 0.002 mm % | Clay < 0.002 mm % | |
| Ladysmith A | 21.68 | 51.36 | 26.96 | 43.68 | 29.36 | 26.96 | Silty clay loam |
| Ladysmith B | 11.76 | 39.28 | 48.96 | 25.92 | 25.12 | 48.96 | Clay |
| Ladysmith C | 11.68 | 45.52 | 42.80 | 29.84 | 27.12 | 42.80 | Silty clay |
| Geary A | 24.00 | 49.44 | 26.56 | 44.16 | 29.28 | 26.56 | Clay loam |
| Geary B | 12.24 | 47.20 | 40.56 | 32.00 | 27.44 | 40.56 | Silty clay |
| Geary C | 18.16 | 43.36 | 38.48 | 40.24 | 21.28 | 38.48 | Silty clay loam |
| Sarpy A | 60.48 | 31.40 | 8.12 | 86.56 | 5.32 | 8.12 | Fine sandy loam |
| Sarpy $C_1$ | 62.28 | 31.32 | 6.40 | 88.48 | 5.12 | 6.40 | Fine sandy loam |
| Sarpy $C_2$ | 50.72 | 42.88 | 6.40 | 85.80 | 7.80 | 6.40 | Fine sandy loam |

Table 4. Distribution of various clay fractions.

| Soil series and horizon | Weight of sample | Total clay <.002mm (%) | Distribution of total clay | | |
|---|---|---|---|---|---|
| | | | Coarse clay 2. - .2μ (%) | Medium clay 0.2 - .08μ (%) | Fine clay <.08μ (%) |
| Ladysmith A | 20 g. | 26.96 | 78.5 | 16.53 | 4.97 |
| Ladysmith B | 20 g. | 48.96 | 93.7 | 5.4 | 0.90 |
| Ladysmith C | 20 g. | 42.80 | 91.0 | 7.4 | 1.6 |
| Geary A | 20 g. | 26.56 | 90.3 | 7.5 | 2.2 |
| Geary B | 20 g. | 40.56 | 86.8 | 8.9 | 4.3 |
| Geary C | 20 g. | 38.48 | 86.7 | 12.4 | 0.9 |
| Sarpy A | 40 g. | 8.12 | 80.0 | 15.0 | 5.0 |
| Sarpy $C_1$ | 40 g. | 6.4 | 83.5 | 13.8 | 2.7 |
| Sarpy $C_2$ | 40 g. | 6.4 | 85.5 | 12.8 | 1.7 |

Table 5. Organic matter content of soils.

| Soil series and horizon | Depth in inches | Sample weight | Titer value, (ml.) | Organic matter (%) |
|---|---|---|---|---|
| Ladysmith A | 0–8 | 0.5 | 14.85 | 4.1 |
| Ladysmith B | 18–24 | 0.5 | 19.10 | 1.54 |
| Ladysmith C | 50–60 | 0.5 | 20.50 | 0.67 |
| Geary A | 0–6 | 0.5 | 15.50 | 3.75 |
| Geary B | 18–24 | 0.5 | 18.80 | 1.74 |
| Geary C | 50–60 | 0.5 | 20.00 | 0.978 |
| Sarpy A | 0–4 | 0.5 | 19.60 | 1.206 |
| Sarpy $C_1$ | 18–24 | 0.5 | 20.15 | 0.938 |
| Sarpy $C_2$ | 50–60 | 0.5 | 20.50 | 0.67 |
| Blank | — | — | 21.60 | 0.0 |

Table 6. Water saturation percentages of soils.

| Soil series and horizon | Weight of air dry soil 2mm. (g.) | Volume of dist $H_2O$ added (ml.) | Saturation (%) |
|---|---|---|---|
| Ladysmith A | 500 | 225 | 45.0 |
| Ladysmith B | 500 | 335 | 67.0 |
| Ladysmith C | 400 | 235 | 58.7 |
| Geary A | 500 | 205 | 41.0 |
| Geary B | 500 | 235 | 47.0 |
| Geary C | 500 | 225 | 45.0 |
| Sarpy A | 500 | 165 | 33.0 |
| Sarpy $C_1$ | 500 | 160 | 32.0 |
| Sarpy $C_2$ | 500 | 170 | 34.0 |

Table 7. Measured pH values for soils.

| Soil series and horizon | Sample weight, (g.) | $H_2O$ added, (ml.) | pH noted at 25°C |
|---|---|---|---|
| Ladysmith A | 20 | 20 | 5.6 |
| Ladysmith B | 20 | 20 | 7.2 |
| Ladysmith C | 20 | 20 | 8.2 |
| Geary A | 20 | 20 | 5.7 |
| Geary B | 20 | 20 | 5.2 |
| Geary C | 20 | 20 | 6.4 |
| Sarpy A | 20 | 20 | 8.0 |
| Sarpy $C_1$ | 20 | 20 | 8.0 |
| Sarpy $C_2$ | 20 | 20 | 8.0 |

Table 8. Water soluble cation contents of soils.

| Soil series and horizon | $Ca^{++}$ |  | $Mg^{++}$ |  | $K^{+}$ |  | $Na^{+}$ |  |
|---|---|---|---|---|---|---|---|---|
|  | ppm. | me./100g. | ppm. | me./100g. | ppm. | me./100g. | ppm. | me./100g. |
| Ladysmith A | 0 | 0 | 0 | 0 | 0.8 | 0.00041 | 4.65 | 0.004 |
| Ladysmith B | 0 | 0 | 0 | 0 | 0.5 | 0.00025 | 10.52 | 0.009 |
| Ladysmith C | 0 | 0 | 0 | 0 | 1.0 | 0.0006 | 13.15 | 0.014 |
| Geary A | 1.5 | 0.0075 | 0 | 0 | 6.12 | 0.0031 | 1.1 | 0.0009 |
| Geary B | 0 | 0 | 0 | 0 | 1.25 | 0.00064 | 1.4 | 0.0009 |
| Geary C | 0 | 0 | 0 | 0 | 0.75 | 0.00038 | .76 | 0.0006 |
| Sarpy A | 0 | 0 | 0 | 0 | 3.25 | 0.00166 | .45 | 0.0004 |
| Sarpy $C_1$ | 0.5 | 0.0025 | 0 | 0 | 1.5 | 0.00076 | .26 | 0.00023 |
| Sarpy $C_2$ | 0 | 0 | 0 | 0 | 9.75 | 0.00038 | 1.0 | 0.0008 |

Table 9. Exchangeable calcium content of soils

| Soil series and horizon | Sample Weight (g.) | Final volume (ml.) | Beckman reading | $Ca^{++}$ content ppm. | me./100g. |
|---|---|---|---|---|---|
| Ladysmith A | 2 | 250 | 35.0 | 20.5 | 12.8 |
| Ladysmith B | 2 | 250 | 51.6 | 38.5 | 24.0 |
| Ladysmith C | 2 | 250 | 62.0 | 50.0 | 31.25 |
| Geary A | 2 | 250 | 42.0 | 27.5 | 17.18 |
| Geary B | 2 | 250 | 41.5 | 27.0 | 16.87 |
| Geary C | 2 | 250 | 41.0 | 26.0 | 16.25 |
| Sarpy A | 2 | 250 | 48.0 | 34.25 | 21.4 |
| Sarpy $C_1$ | 2 | 250 | 50.0 | 36.5 | 22.8 |
| Sarpy $C_2$ | 2 | 250 | 47.0 | 33.0 | 20.6 |

Table 10. Exchangeable magnesium content of soils.

| Soil series and horizon | Sample Weight (g.) | Final volume (ml.) | Beckman reading | $Mg^{++}$ content ppm. | me./100g. |
|---|---|---|---|---|---|
| Ladysmith A | 2 | 250 | 69.0 | 1.25 | 1.3 |
| Ladysmith B | 2 | 250 | 75.0 | 7.5 | 7.8 |
| Ladysmith C | 2 | 250 | 75.0 | 7.5 | 7.8 |
| Geary A | 2 | 50 | 85.0 | 21.0 | 4.4 |
| Geary B | 2 | 250 | 78.0 | 10.02 | 10.4 |
| Geary C | 2 | 50 | 90.0 | 27.5 | 5.7 |
| Sarpy A | 2 | 50 | 69.0 | 0.0 | 0.0 |
| Sarpy $C_1$ | 2 | 50 | 70.0 | 1.5 | 0.31 |
| Sarpy $C_2$ | 2 | 50 | 68.0 | 4.0 | 0.83 |

Table 11. Exchangeable potassium content of soils.

| Soil series and horizon | Sample weight (g.) | Final volume (ml.) | Beckman reading | $K^+$ content | |
|---|---|---|---|---|---|
| | | | | ppm. | me/100g. |
| Ladysmith A | 2 | 250 | 19.5 | 4.3 | 1.3 |
| Ladysmith B | 2 | 250 | 25.0 | 5.5 | 1.76 |
| Ladysmith C | 2 | 250 | 27.6 | 6.25 | 2.0 |
| Geary A | 2 | 250 | 40.0 | 9.5 | 3.04 |
| Geary B | 2 | 250 | 30.2 | 7.05 | 2.25 |
| Geary C | 2 | 250 | 29.0 | 6.52 | 2.08 |
| Sarpy A | 2 | 250 | 27.0 | 6.12 | 1.95 |
| Sarpy $C_1$ | 2 | 250 | 21.5 | 4.52 | 1.45 |
| Sarpy $C_2$ | 2 | 250 | 15.6 | 3.15 | 1.00 |

Table 12. Exchangeable sodium content of soils.

| Soil series and horizon | Sample weight (g.) | Final volume (ml.) | Beckman reading | $Na^+$ content of soils | |
|---|---|---|---|---|---|
| | | | | ppm. | me./100g. |
| Ladysmith A | 2 | 250 | 19.2 | 1.05 | 0.57 |
| Ladysmith B | 2 | 250 | 63.3 | 5.4 | 2.90 |
| Ladysmith C | 2 | 250 | 69.0 | 6.05 | 3.28 |
| Geary A | 2 | 250 | 9.0 | 0.26 | 0.14 |
| Geary B | 2 | 250 | 13.0 | 0.60 | 0.32 |
| Geary C | 2 | 250 | 16.0 | 0.75 | 0.40 |
| Sarpy A | 2 | 250 | 8.0 | 0.25 | 0.13 |
| Sarpy $C_1$ | 2 | 250 | 9.0 | 0.26 | 0.14 |
| Sarpy $C_2$ | 2 | 250 | 14.0 | 0.65 | 0.35 |

Table 13. Cation exchange capacities of soils before oxidation of organic matter.

| Soil series and horizon | Sample weight (g.) | Final volume (ml.) | Beckman reading | Cation exchange capacity me./100g. |
|---|---|---|---|---|
| Ladysmith A | 2 | 250 | 60.0 | 29.69 |
| Ladysmith B | 2 | 250 | 80.6 | 45.00 |
| Ladysmith C | 2 | 250 | 85.0 | 48.70 |
| Geary A | 2 | 250 | 56.0 | 26.88 |
| Geary B | 2 | 250 | 61.0 | 30.31 |
| Geary C | 2 | 250 | 58.0 | 28.12 |
| Sarpy A | 2 | 250 | 54.0 | 25.47 |
| Sarpy $C_1$ | 2 | 250 | 56.0 | 26.88 |
| Sarpy $C_2$ | 2 | 250 | 50.0 | 22.80 |

Table 14. Summary of exchangeable cations and cation exchange capacities of the soils.

| Soil series and horizon | Exchangeable cations, me./100g. | | | | | Cation exchange capacity, me./100g. |
|---|---|---|---|---|---|---|
| | $Ca^{++}$ | $Mg^{++}$ | $K^{+}$ | $Na^{+}$ | $H^{+}$ | |
| Ladysmith A | 12.8 | 1.3 | 1.3 | 0.57 | 13.72 | 29.69 |
| Ladysmith B | 24.0 | 7.8 | 1.76 | 2.9 | 8.54 | 45.0 |
| Ladysmith C | 31.25 | 7.8 | 2.00 | 3.28 | 4.37 | 48.7 |
| Geary A | 17.18 | 4.4 | 3.04 | 0.14 | 2.12 | 26.88 |
| Geary B | 16.87 | 10.4 | 2.25 | 0.32 | 0.47 | 30.31 |
| Geary C | 16.25 | 5.7 | 2.08 | 0.40 | 3.69 | 28.12 |
| Sarpy A | 21.4 | 0.0 | 1.95 | 0.13 | 1.99 | 25.47 |
| Sarpy $C_1$ | 22.8 | 0.31 | 1.45 | 0.14 | 2.18 | 26.88 |
| Sarpy $C_2$ | 20.6 | 0.83 | 1.00 | 0.35 | 0.02 | 22.8 |

Table 15. Calculated percentages of base saturation.

| Soil series and horizon | Total exchangeable bases $Ca^{++} + Mg^{++} + K^{+} + Na^{+}$ (me./100g.) | Exchange capacity (me./100g.) | Base saturation (%) | pH@ 25°C |
|---|---|---|---|---|
| Ladysmith A | 15.97 | 29.69 | 53.8 | 5.6 |
| Ladysmith B | 36.46 | 45.00 | 81.0 | 7.2 |
| Ladysmith C | 44.33 | 48.70 | 91.0 | 8.2 |
| Geary A | 24.76 | 26.88 | 92.0 | 5.7 |
| Geary B | 29.84 | 30.31 | 98.4 | 5.2 |
| Geary C | 24.43 | 28.12 | 87.3 | 6.4 |
| Sarpy A | 23.48 | 25.47 | 92.2 | 8.0 |
| Sarpy $C_1$ | 24.39 | 26.88 | 90.7 | 8.0 |
| Sarpy $C_2$ | 22.31 | 22.80 | 98.0 | 8.0 |

Table 16. Quantities of exchangeable cations in pounds per acre.

| Soil series and horizon | Exchangeable cations, pounds per acre | | | |
|---|---|---|---|---|
| | $Ca^{++}$ | $Mg^{++}$ | $K^{+}$ | $Na^{+}$ |
| Ladysmith A | 5,120 | 312 | 1014 | 262 |
| Ladysmith B | 9,600 | 1870 | 1372 | 1330 |
| Ladysmith C | 12,500 | 1870 | 1560 | 1510 |
| Average | 9,076 | 1350 | 1315 | 1034 |
| | | | | |
| Geary A | 6,870 | 1080 | 2376 | 64.5 |
| Geary B | 6,750 | 2500 | 1755 | 147 |
| Geary C | 6,500 | 1370 | 1620 | 184 |
| Average | 6,673 | 1650 | 1917 | 132 |
| | | | | |
| Sarpy A | 8,550 | 0.0 | 1520 | 59.8 |
| Sarpy $C_1$ | 9,120 | 77.4 | 1130 | 64.5 |
| Sarpy $C_2$ | 8,250 | 199.0 | 780 | 161 |
| Average | 8,640 | 92.1 | 1143 | 95.1 |

Table 17. Proportion of total exchange capacity occupied by various cations.

| Soil series and horizon | Percent of exchange capacity | | | | |
|---|---|---|---|---|---|
| | $Ca^{++}$ | $Mg^{++}$ | $K^{+}$ | $Na^{+}$ | $H^{+}$ |
| Ladysmith A | 43.10 | 4.38 | 4.38 | 1.93 | 46.21 |
| Ladysmith B | 53.3 | 17.35 | 3.90 | 6.45 | 19.0 |
| Ladysmith C | 64.2 | 16.02 | 4.10 | 6.75 | 8.93 |
| Average | 53.5 | 12.8 | 4.1 | 5.0 | 24.7 |
| Geary A | 64.0 | 16.3 | 11.7 | 0.52 | 7.48 |
| Geary B | 56.0 | 34.0 | 7.5 | 1.04 | 1.56 |
| Geary C | 57.8 | 20.3 | 7.3 | 1.40 | 13.20 |
| Average | 59.2 | 23.5 | 8.8 | .98 | 7.4 |
| Sarpy A | 84.2 | 0.0 | 7.5 | 0.5 | 7.8 |
| Sarpy $C_1$ | 84.8 | 1.2 | 5.4 | 0.5 | 8.1 |
| Sarpy $C_2$ | 90.0 | 3.6 | 4.4 | 1.2 | 0.8 |
| Average | 86.3 | 1.6 | 5.7 | .73 | 5.6 |

Table 18. Cation exchange capacity (after oxidation of organic matter ) of mineral portion of soils.

| Soil series and horizon | Sample weight (g.) | Final volume (ml.) | Beckman reading | Cation exchange capacity me./100g. |
|---|---|---|---|---|
| Ladysmith A | 2 | 250 | 51.0 | 23.4 |
| Ladysmith B | 2 | 250 | 72.6 | 38.8 |
| Ladysmith C | 2 | 250 | 69.0 | 36.2 |
| Geary A | 2 | 250 | 50.0 | 22.8 |
| Geary B | 2 | 250 | 61.0 | 30.03 |
| Geary C | 2 | 250 | 52.6 | 24.0 |
| Sarpy A | 2 | 250 | 40.5 | 19.7 |
| Sarpy $C_1$ | 2 | 250 | 40.4 | 19.7 |
| Sarpy $C_2$ | 2 | 250 | 40.2 | 17.5 |

Table 19. Distribution of cation exchange capacity between mineral and organic materials.

| Soil series and horizon | Total cation exchange capacity, Mineral + organic me./100g. | Cation exchange due to mineral matter |  | Cation exchange due to organic matter |  |
|---|---|---|---|---|---|
|  |  | Absolute value me./100g. | % | % | Absolute value me./100g. |
| Ladysmith A | 29.7 | 23.4 | 79 | 21 | 6.3 |
| Ladysmith B | 45.0 | 38.8 | 86.2 | 13.8 | 6.2 |
| Ladysmith C | 48.7 | 36.2 | 74.3 | 25.7 | 12.5 |
| Average | 41.1 | 32.8 | 79.8 | 20.2 | 8.3 |
| Geary A | 26.9 | 22.8 | 84.6 | 15.4 | 4.1 |
| Geary B | 30.3 | 30.0 | 99.0 | 1.0 | 0.3 |
| Geary C | 28.1 | 24.0 | 85.4 | 14.6 | 4.1 |
| Average | 28.4 | 25.6 | 89.7 | 10.3 | 2.8 |
| Sarpy A | 25.5 | 16.3 | 64.0 | 36.0 | 9.2 |
| Sarpy $C_1$ | 26.9 | 16.2 | 60.4 | 39.6 | 10.7 |
| Sarpy $C_2$ | 22.8 | 15.9 | 68.0 | 32.0 | 6.9 |
| Average | 25.06 | 16.1 | 64.1 | 35.9 | 8.9 |

Table 20. Ladysmith A, X-ray diffraction data.

| 2 – 0.2µ | | | 0.2 µ-0.08µ | | | < 0.08µ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing A° | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 17.263 | W | Montmorillonite interstratified with Illite[3] | | | | 15.538 | S | Montmorillonite interstratified with Illite |
| 9.869 | W | Illite[2] | 10.062 | S | Illite | | | |
| 7.186 | V W | Kaolinite[4] | | | | | | |
| 4.498 | S | Montmorillonite[1] | 4.5843 | V S | Montmorillonite | 4.4864 | V S | Montmorillonite |
| 4.298 | V W | Kaolinite | | | | | | |
| 3.326 | V S | Illite | 3.4335 | M | Kaolinite | 3.347 | M | Illite |
| 2.6027 | M | Montmorillonite | 2.6253 | M | Montmorillonite | 2.584 | M | Montmorillonite |
| 1.839 | V W | Kaolinite | | | | 1.956 | V W | Illite |
| 1.5145 | M | Montmorillonite | 1.5256 | M | Montmorillonite | 1.685 | V W | Montmorillonite |
| 1.3886 | V W | Kaolinite | | | | 1.59 | V W | Montmorillonite |
| 1.33 | V W | Montmorillonite | 1.33 | W | Montmorillonite | 1.29 | W | Montmorillonite |

1. Montmorillonite 2. Illite 3. Montmorillonite interstratified with Illite 4. Kaolite

Table 21. Ladysmith B, X-ray diffraction data.

| 2 – 0.2µ | | | 0.2µ – 0.08µ | | | < 0.08µ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 16.866 | W | Montmorillonite interstratified with Illite[3] | 14.864 | M | Montmorillonite interstratified with Illite | 14.864 | S | Montmorillonite interstratified with Illite |
| 7.2569 | W | Kaolinite[4] | 3.4559 | S | Kaolinite | 4.4864 | V S | Montmorillonite |
| 4.486 | S | Montmorillonite[1] | 3.3746 | W | Kaolinite | 3.347 | M | Montmorillonite |
| 4.267 | W | Kaolinite | 2.584 | M | Montmorillonite | 2.6114 | M | Montmorillonite |
| 3.326 | V S | Illite[2] | 1.6903 | W | Montmorillonite | 1.697 | W | Montmorillonite |
| 2.5769 | M | Montmorillonite | 1.5073 | M | Montmorillonite | 1.5002 | W | Montmorillonite |
| 2.1735 | W | Illite | 1.3006 | V W | Montmorillonite | 1.2899 | V W | Montmorillonite |
| 1.505 | M | Montmorillonite | 1.2601 | W | Montmorillonite | 1.2434 | V W | Montmorillonite |
| 1.3784 | V W | Kaolinite | | | | | | |
| 1.3016 | V W | Montmorillonite | | | | | | |

1. Montmorillonite 2. Illite 3. Montmorillonite interstratified with Illite 4. Kaolinite

Table 22. Ladysmith C, X-ray diffraction data.

| 2 – 0.2µ | | | 0.2µ – 0.08µ | | | < 0.08µ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 20.755 | V S | Montmorillonite[1] | 15.082 | V S | Montmorillonite interstratified with Illite[4] | 15.538 | V S | Montmorillonite interstratified with Illite |
| 8.851 | W | Montmorillonite | 4.4864 | V S | Montmorillonite | 4.4864 | V S | Montmorillonite |
| 4.4864 | S | Montmorillonite | 3.347 | W | Illite[2] | 2.5781 | M | Illite |
| 4.267 | W | Kaolinite[3] | 2.578 | M | Illite | 1.695 | V W | Montmorillonite |
| 3.326 | M | Illite | 1.707 | W | Montmorillonite | 1.5037 | W | Montmorillonite |
| 2.566 | M | Montmorillonite | 1.5037 | W | Montmorillonite | 1.297 | V W | Montmorillonite |
| 1.5037 | W | Illite | 1.299 | V W | Montmorillonite | | | |
| 1.3018 | V W | Montmorillonite | 1.2351 | V W | | | | |

1. Montmorillonite 2. Illite 3. Kaolinite 4. Montmorillonite interstratified with Illite

Table 23. Geary A, X-ray diffraction data.

| 2µ – 0.2µ |  |  | 0.2µ – 0.08µ |  |  | < 0.08µ |  |  |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 16.540 | W | Montmorillonite interstratified with Illite[5] | 15.307 | S | Montmorillonite interstratified with Illite | 15.062 | M | Montmorillonite interstratified with Illite |
| 9.926 | W | Montmorillonite[1] | 9.869 | W | Montmorillonite | 7.339 | W | Montmorillonite |
| 7.2366 | V W | Metahalloysite[4] | 4.486 | V S | Montmorillonite | 4.486 | S | Montmorillonite |
| 4.6254 | S | Montmorillonite | 3.347 | M W | Illite | 3.347 | M | Illite |
| 4.2775 | W | Illite[2] | 2.566 | M | Montmorillonite | 2.2659 | M | Montmorillonite |
| 3.347 | S | Illite | 1.707 | W | Montmorillonite | 1.6998 | W | Montmorillonite |
| 2.5781 | M | Montmorillonite | 1.5002 | W | Montmorillonite | 1.5055 | M | Montmorillonite |
| 2.1324 | W | Illite | 1.297 | V W | Montmorillonite | 1.297 | W | Montmorillonite |
| 1.979 | V W | Illite | 1.256 | V W | Montmorillonite | 1.2487 | V W | Montmorillonite |
| 1.8164 | W | Kaolinite[3] |  |  |  |  |  |  |
| 1.5403 | W | Montmorillonite |  |  |  |  |  |  |
| 1.5037 | W | Montmorillonite |  |  |  |  |  |  |

1. Montmorillonite 2. Illite 3. Kaolinite 4. Metahalloysite 5. Montmorillonite interstratified with Illite

Table 24. Geary B, X-ray diffraction data.

| 2μ – 0.2μ | | | 0.2μ – 0.08μ | | | 0.08μ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 16.023 | M | Montmorillonite interstratified with Illite[3] | 15.082 | M | Montmorillonite interstratified with Illite | 15.538 | S | Montmorillonite interstratified with Illite |
| 4.486 | S | Montmorillonite[1] | 4.486 | V S | Montmorillonite | 4.4864 | V S | Montmorillonite |
| 4.2156 | W | Kaolinite[4] | 3.347 | M | Illite | 3.3576 | W | Illite |
| 3.3365 | V S | Illite[2] | 2.572 | S | Montmorillonite | 2.313 | S | Montmorillonite |
| 2.572 | M | Montmorillonite | 1.6926 | V W | Montmorillonite | 1.7046 | W | Montmorillonite |
| 2.1569 | W | Illite | 1.5012 | W | Montmorillonite | 1.5055 | M | Montmorillonite |
| 1.4967 | W | Montmorillonite | 1.297 | V W | Montmorillonite | 1.2994 | M | Montmorillonite |
| 1.3772 | V W | Montmorillonite | 1.2476 | V W | Montmorillonite | 1.2551 | W | Montmorillonite |
| 1.2994 | V W | Montmorillonite | | | | | | |

1. Montmorillonite 2. Illite 3. Montmorillonite interstratified with Illite 4. Kaolinite

Table 25. Geary C, X-ray diffraction data.

| 2.0 – 0.2μ | | | 0.2 – 0.08μ | | | < 0.08μ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 15.538 | W | Montmorillonite interstratified with Illite[4] | 15.082 | M | Montmorillonite interstratified with Illite | 15.307 | M | Montmorillonite interstratified with Illite |
| 9.869 | V W | Illite[2] | 4.486 | V S | Montmorillonite | 7.339 | W | Kaolinite |
| 7.2366 | V W | Kaolinite[3] | 3.347 | W | Illite | 4.486 | V S | Montmorillonite |
| 4.4673 | S | Montmorillonite[1] | 2.5757 | S | Montmorillonite | 3.347 | S | Illite |
| 4.2497 | M | Kaolinite | 1.6926 | W | Montmorillonite | 2.289 | S | —— |
| 3.3365 | V S | Illite | 1.5002 | M | Montmorillonite | 1.707 | W | Montmorillonite |
| 2.5721 | M | Montmorillonite | 1.2958 | V W | Montmorillonite | 1.5073 | W | Montmorillonite |
| 1.9838 | W | Illite | | | | 1.3115 | W | |
| 1.822 | W | Kaolinite | | | | 1.254 | W | |
| 1.5395 | W | Illite | | | | | | |
| 1.502 | M | Montmorillonite | | | | | | |
| 1.3772 | V W | Montmorillonite | | | | | | |

1. Montmorillonite 2. Illite 3. Kaolinite 4. Montmorillonite interstratified with Illite

Table 26. Sarpy A, X-ray diffraction data.

| 2.0 – 0.2μ |  |  | 0.2 – 0.08μ |  |  | 0.08μ |  |  |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 17.091 | W | Montmorillonite interstratified with Illite[2] | 14.651 | S | Montmorillonite interstratified with Illite | 12.51 | M | Montmorillonite interstratified with Illite |
| 9.504 | W | Montmorillonite[1] | 10.161 | W | Illite | 4.4864 | V S | Montmorillonite |
| 4.4864 | V S | Montmorillonite | 4.4864 | V S | Montmorillonite | 3.3639 | S | Illite |
| 3.347 | S | Illite[3] | 3.347 | M | Illite | 3.0593 | W | —— |
| 2.572 | M | Montmorillonite | 2.566 | S | Montmorillonite | 2.56 | W | Montmorillonite |
| 1.502 | W | Montmorillonite | 1.7046 | W | Montmorillonite | 1.7158 | W | Montmorillonite |
|  |  |  | 1.5037 | M | Montmorillonite | 1.5109 | W | Montmorillonite |
|  |  |  | 1.2958 | W | Montmorillonite |  |  |  |
|  |  |  | 1.2508 | W | Montmorillonite |  |  |  |

1. Montmorillonite 2. Montmorillonite interstratified with Illite 3. Illite

Table 27. Sarpy $C_1$, X-ray diffraction data.

| 2.0 – 0.2μ | | | 0.2 – 0.08μ | | | < 0.08μ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 15.777 | V S | Montmorillonite interstratified with Illite[5] | 14.365 | M | Vermiculite[2] | 15.082 | M | Montmorillonite interstratified with Illite |
| 9.5045 | W | Illite[3] | 9.775 | W | Montmorillonite | 10.263 | W | Montmorillonite |
| 7.1366 | V W | Kaolinite[4] | 4.486 | V S | Montmorillonite | 4.486 | V S | Montmorillonite |
| 4.302 | V S | Kaolinite | 3.3746 | V W | Illite | 3.347 | W | Illite |
| 3.2749 | S | Kaolinite | 2.5904 | S | Montmorillonite | 2.581 | S | Montmorillonite |
| 2.5246 | S | Montmorillonite | 1.695 | V W | Montmorillonite | 2.582 | W | Montmorillonite |
| 1.4828 | W | Montmorillonite | 1.5073 | M | Montmorillonite | 1.709 | W | Montmorillonite |
| 1.3499 | V W | Montmorillonite | 1.2982 | W | Montmorillonite | 1.504 | M | Montmorillonite |
| 1.284 | V W | Montmorillonite | | | | 1.3018 | W | Montmorillonite |
| | | | | | | 1.3018 | W | Montmorillonite |

1. Montmorillonite 2. Vermivulite 3. Illite 4. Kaolite 5. Montmorillonite interstratified with Illite

Table 23. Sarpy $C_2$. X-ray diffraction data.

| 2.0 – 0.2μ | | | 0.2 – 0.08μ | | | < 0.08μ | | |
|---|---|---|---|---|---|---|---|---|
| Basal spacing | I | Mineral | Basal spacing | I | Mineral | Basal spacing | I | Mineral |
| 15.777 | V S | Montmorillonite interstratified with Illite[5] | 14.864 | V S | Vermiculite[4] | 16.540 | S | Montmorillonite interstratified with Illite |
| 9.869 | W | Illite[2] | 9.775 | V W | Illite | 9.332 | W | Montmorillonite |
| 7.039 | W | Kaolinite[3] | 4.4864 | V S | Montmorillonite | 4.4864 | V S | Montmorillonite |
| 4.4103 | V S | Kaolinite | 3.3639 | M | Illite | 3.347 | W | Illite |
| 3.4005 | S | Illite | 2.6127 | M | Montmorillonite | 2.572 | M | Montmorillonite |
| 2.5517 | M | Montmorillonite[1] | 1.6998 | W | Montmorillonite | 2.3877 | W | Kaolinite |
| 1.4967 | M | Montmorillonite | 1.509 | W | Montmorillonite | 1.6998 | W | Montmorillonite |
| 1.3716 | W | Montmorillonite | 1.297 | W | Montmorillonite | 1.4967 | M | Montmorillonite |
| 1.297 | W | Montmorillonite | | | | 1.291 | V W | Montmorillonite |
| | | | | | | 1.2434 | V W | Montmorillonite |

1. Montmorillonite 2. Illite 3. Kaolinite 4. Vermiculite 5. Montmorillonite interstratified with Illite

Table 29. Summary of clay minerals in various soils.

| Soil series and horizon | Clay mineral present |
|---|---|
| Ladysmith A | Montmorillonite, Illite, Kaolinite and Montmorillonite interstratified with Illite. |
| Ladysmith B | Montmorillonite, Illite, Kaolinite and Montmorillonite interstratified with Illite. |
| Ladysmith C | Montmorillonite, Illite, Kaolinite and Montmorillonite interstratified with Illite. |
| Geary A | Montmorillonite, Illite,Kaolinite and Montmorillonite interstratified with Illite. |
| Geary B | Montmorillonite, Illite, Kaolinite and Montmorillonite interstratified with Illite. |
| Geary C | Montmorillonite, Illite, Kaolinite and Montmorillonite interstratified with Illite. |
| Sarpy A | Montmorillonite, Illite and Montmorillonite interstratified with Illite. |
| Sarpy $C_1$ | Montmorillonite, Illite, Vermiculite and Kaolinite and Montmorillonite interstratified with Illite. |
| Sarpy $C_2$ | Montmorillonite, Illite, Kaolinite, Vermiculite and Montmorillonite interstratified with Illite. |

## DISCUSSION

### Mechanical Analysis

It is a known fact that the important physicochemical phenomena in soils are influenced by the amount of surface per unit of soil mass. The tremendous increase in surface area is the result of the increased subdivisions of the soil separates. This Thesis deals mainly with the surface phenomena, i.e. cation exchange, in which surfaces play a significant part. In order to understand the exchange complex in different soils, we need to know the major components of the soils, their nature and proportion. Consequently much emphasis has to be laid on clay content and its type or species under this type of study.

Soil separates by their presence in significant quantities characterize the soil. For instance, sand separates tend to function as individual particles. The dominance of this fraction characterizes the soil by low cohesion, low plasticity and low water holding capacity. Such soils drain excessively, warm early in spring and are generally known as light or early or warm soils. Sarpy fine sandy loam comes under this category. Sarpy fine sandy loam contains 6-8 percent clay, 31 to 42 percent silt and 50 to 60 percent sand.

Soil separates in Ladysmith soil series range - sand 11 to 21 percent, silt 39 to 51 percent and clay 27 to 49 percent. Finer fractions of silt and clay are dominant. The B horizon shows considerable accumulation of clay (49 percent). Similar is the case with Geary series, except that the clay content is slightly less ranging 26 to 40 percent. Here too, B horizon shows accumulation of clay. In view of the general make-up of these two series it may be stated here that these two series show cohesion and adsorption to a marked degree. Air and water movements may be restricted. Hence these soils can be classes as 'heavy', 'cold' or 'late'. Water saturation percentage determined in these soils, supports these conclusions markedly.

Based on mechanical analysis and following the U.S.D.A. system of classification these soil series are classified into different textural groups:

Ladysmith series - A horizon (0-8"), silty clay loam
Ladysmith series - B horizon (18-24"), clay
Ladysmith series - C horizon (50-60"), silty clay

Geary series-A horizon (0-8"), clay loam
Geary series-B horizon (18-24"), silty clay
Geary series-C horizon (50-60"), silty clay loam

Sarpy series - A horizon (0-4"), fine sandy loam
Sarpy series - $C_1$ horizon (18-24"), fine sandy loam
Sarpy series - $C_2$ horizon (50-60"), fine sandy loam

## Water Holding Capacity

Water saturation percent may be taken as an estimation for this value. Ladysmith silty clay loam had a water saturation of 45 percent. Ladysmith Clay (B) had a value as high as 67 percent. Ladysmith silty clay (C) had 58 .7 percent of water saturation.

Water saturation in Geary clay loam (A horizon) was 41 percent, in

Geary silty clay 47 percent and in Geary silty clay loam it was 45 percent. These three horizons were quite uniform in this respect.

Sarpy series gave these values as--Sarpy fine sandy loam (A horizon), 33 percent,in $C_1$ horizon, fine sandy loam showed 32 percent water holding capacity, and in $C_2$ fine sandy loam analysed 34 percent. These values are quite uniform since the testure is the same.

## Organic Matter Content

Miller (24) gave the organic matter content of some of the Kansas soils. According to him, 18 silt loams of Eastern Kansas contained 4.54 percent of organic matter and 11 clay loams of western Kansas contained 3.83 percent of organic matter. Ladysmith series — in A horizon which is silty clay loam analysed 4.1 percent organic matter. In B horizon, clay soil type showed 1.54 percent and in C horizon, silty clay showed 0.67 percent of organic matter.

In Geary series the organic matter content was as follows; In A horizon, Geary clay loam contained 3.75 percent organic matter, in B horizon Geary silty clay contained 1.74 percent, while in C horizon Geary silty clay loam had 0.6 percent of organic matter.

Sarpy series was comparatively low in organic matter. It might be due to its being under cultivation.

The Sarpy profile, composed of fine sandy loam throughout, had organic matter contents of 1.2 percent, 0.94 percent and 0.7 percent respectively, in the A, $C_1$ and $C_2$ horizon.

Organic matter on decomposition yields humus which has a valuable property of adsorbing nutrient cations and releasing them for plant use.

This property of cation exchange in soils has been ascribed to (a) the carboxyl groups, (b) phenol hydroxy groups and (c) nitrogen free substances and the protein linkage of the ligno-proteinates.

Barshad (1) has reported the extent of cation exchange capacity due to organic matter from the minimum of 6.9 percent to the maximum of 40, 60 or even 80 percent, depending upon the organic matter content and its state of decomposition.

In Ladysmith soil series cation exchange capacity due to humus varied from 13.8 percent to 25.7 percent of the total exchange capacity (Table 19). In Ladysmith silty clay loam, 21 percent of the total exchange capacity was due to organic matter while in clay or B horizon and silty clay of C horizon it was 13.8 percent and 25.7 percent respectively. On the average 20 percent of the total exchange capacity was due to organic fraction.

In Geary series contribution of organic matter to the cation exchange capacity was as follows:

In A horizon (clay loam) 15.4 percent of cation exchange capacity was due to organic matter and 1.0 percent and 14.6 percent in B and C horizons respectively was due to organic matter. On the average in these types the contribution of organic matter to the cation exchange capacity was 10.3 percent of the total.

In Sarpy series, where the soil type was fine sandy loam throughout the profile, the contribution of organic fraction to cation exchange capacity amounted to 36 percent in A, 39.6 percent in $C_1$ and 32 percent in $C_2$ horizons.

## Exchangeable Cations

In Ladysmith series in A horizon the soil class was silty clay loam. In this layer $Ca^{++}$ amounted to 12.8 me. per 100 g. of soil, in B horizon where the soil class was clay, $Ca^{++}$ ions occupied 24 me. per 100 g. of soil and in C horizon where the soil was silty clay, $Ca^{++}$ ions occupied 31.25 me. per 100 g. of soil. There was an increase in the exchangeable $Ca^{++}$ ion with an increase in depth up to C horizon. Calcium was the dominant ion throughout the profile. Its quantity in surface layer was 5120 pounds per acre, 9600 pounds per acre in B horizon and 12,500 pounds per acre in C horizon. This ion constituted 43.1 percent, 53.3 percent and 64.2 percent of the total exchange capacities of the A, B and C horizons, respectively. On the average it occupied 53.5 percent of the cation exchange capacity throughout the profile.

Magnesium exchangeable ion was present in the concentration of 1.3 me. per 100 g. of soil in A horizon, 7.8 me. in B and C horizons. The amount of exchangeable magnesium present in this series was 312 pounds per acre in A horizon, 1870 pounds per acre in B horizon and C horizon. This constituted 4.38 percent in A, 17.35 percent in B, and 16.02 percent in C horizons respectively. The B and C horizons were rich in the exchangeable magnesium as compared to A horizon. On the average exchangeable magnesium forms 12.8 percent of the total cation exchange capacity in Ladysmith soil series. This is the third most abundant cation.

The concentration of the exchangeable potassium ions in Ladysmith silty clay loam in A horizon was 1.3 me. per 100 g. of soil, 1.76 me. per 100 g. in the B horizon, and 2.0 me. per 100 g. of soil in C horizon. Exchangeable potassium tends to increase with an increase in depth of profile. The total quantity of exchangeable potassium ion was 1014 pounds per acre in A horizon, 1372 pounds per acre in B horizon, and 1560 pounds per acre in C horizon. This constituted 4.33 percent in A horizon, 3.9 percent in B horizon and 4.1 percent in C horizon of the total cation exchange capacity. On the average it formed 4.1 percent of the total cation exchange capacity. Potassium was the least abundant exchangeable cation in the Ladysmith soil.

The concentration of exchangeable sodium in Ladysmith soil was 0.57 me. per 100 g. of soil in A horizon, 2.9 me. per 100 g. of soil in B horizon and 3.28 me. per 100 g. of soil in C horizon. The absolute quantities of this ion were 262 pounds per acre in A horizon, 1330 pounds per acre in B horizon, 1510 pounds per acre in C horizon. Exchangeable sodium ion forms 1.93 percent in A horizon, 6.45 percent in B horizon and 6.75 percent in C horizon of the total exchange capacity. This cation ranked fourth in abundance in the Ladysmith soil.

The concentration of exchangeable hydrogen ions was highest in A horizon, i.e. 13.72 me. per 100 g. of soil or 46.21 percent of the cation exchange capacity. The B horizon contained 8.54 me. per 100 g. of soil or had 19.0 percent of the total exchange capacity occupied by exchangeable hydrogen and C horizon contained 4.37 me. per 100 g. of soil or had 9 percent of the total exchange capacity occupied by this cation.

In Ladysmith soil series the concentration of the exchangeable bases ($Ca^{++}$, $Mg^{++}$, $K^{+}$, and $Na^{+}$) increased in the lower layer of the profile and the concentration of hydrogen ion decreased with greater depth of profile. This indicates leaching of bases to lower strata. This is further indicated by the base saturation percentages of the A, B and C horizons. The base saturation percentage in A horizon was 53.8 percent, 81 percent in B and 91 percent in C horizon. The corresponding pH values were 5.6,7.2, and 8.2, respecitvely. This showed clearly that as the base saturation increased, the pH of the soil also increased. The abundance of the cations in Ladysmith soil in the descending order was as follows:

$$Ca > H > Mg > Na > K$$

In Geary series exchangeable $Ca^{++}$ was 17.14 me. per 100 g. of soil in A horizon, 16.87 me. per 100 g. in B horizon, 16.23 me. per 100 g. in C horizon. The actual quantities of the exchangeable calcium in A,B, and C horizons were 6,870 pounds per acre, 6766 pounds per acre and 6500 pounds per acre, respectively. The distribution was quite uniform throughout the profile. These values were 64.0 percent 56.0 percent and 57.0 percent of the respective cation exchange capacities in A, B, and C horizons.

The concentration of exchangeable magnesium ions varies considerably in the profile. It was 4.4 me per 100 g. soil in A horizon, 10.4 me.per 100 g. in B horizon and 5.7 me. per 100 g. in C horizon. The respective quantities were 1080 pounds per acre, 2500 pounds per acre and 1370 pounds per acre. These values were 16.3 percent of the total exchange capacity in A horizon, 34.0 percent of the cation exchange capacity in B horizon and 20 percent of the exchange capacity in C horizon. There was considerable accumulation of magnesium ions in the B horizon of this soil.

The exchangeable potassium content in this soil was 3.04 me. per 100 g. in A horizon, 2.25 me. per 100 g. in B horizon and 2.08 me. per 100 g. in C horizon. The actual quantities were 2376 pounds per acre in A horizon, 1755 pounds per acre in B horizon and 1620 pounds per acre in C horizon.

This constituted 11.7 percent of the cation exchange capacity in A horizon, 7.5 percent and 7.3 percent in B and C horizons, respectively. The surface layer was considerably richer in this ion as compared to the subsoil layers.

The concentration of the exchangeable sodium in this soil was only 0.14 me. per 100 g. in A horizon, 0.32 me. per 100 g. in B horizon and 0.40 me. per 100 g. of soil in C horizon. The actual amounts of this cation present was 64 pounds per acre in A horizon, 147 pounds per acre in B horizon and 184 pounds per acre in C horizon. These quantities constituted 0.52 percent, 1.04 percent and 1.4 percent of the total exchange capacities of the respective horizons. The B and C horizons had considerably more of this element than the surface horizon.

The concentration of exchangeable hydrogen in Geary series was 2.12 me. per 100 g. of soil in A horizon, 0.47 me. in B horizon and 3.69 me. per 100 g. in C horizon. This ion formed 4.48 percent in A, 1.56 percent in B and 13.2 percent in C horizon of the total exchange capacity.

The general picture of the exchangeable cations as a whole in Geary soil was such that the calcium ion was the most abundant followed by magnesium, potassium and hydrogen. Sodium ion was in least quantities. The decreasing order of abundance was as follows:

$$Ca > Mg > K > H > Na$$

The extent of base saturation in A horizon was 92 percent, 98.4 percent in B horizon, and 87.3 percent in C horizon.

Sarpy series contained 21.4 me. per 100 g. of exchangeable Calcium$^{++}$ in A horizon, (plow layer), 22.8 me. per 100 g. of soil in $C_1$ horizon and 20.6 me. per 100 g. in $C_2$ horizon. The actual quantities present were 8550 pounds per acre in A horizon, 9120 pounds per acre in $C_1$ horizon and 8250 pounds per acre in $C_2$ horizon. The calcium ion was the most abundant of all. It occupied 84.2 percent of the total exchange capacity in A layer while in B and C it comprised 84.8 and 90 percent of the exchange capacities, respectively.

The exchangeable magnesium in Sarpy fine sandy loam was as follows:

The plow layer of this soil had none. In $C_1$ horizon, there was only 0.31 me. per 100 g. soil while in the $C_2$ horizon it amounted to 0.83 me. per 100 g. The total quantities are 0 pounds per acre, 77 pounds per acre and 199 pounds per acre in A, $C_1$ and $C_2$ horizons, respectively. This formed 0, 1.2 percent and 3.6 percent of the total cation exchange capacity. These quantities of exchangeable magnesium were very low as compared to other series.

Exchangeable potassium in this soil amounted to 1.95 me. per 100 g. in A layer, 1.45 me. per 100 g. in $C_1$ layer and 1.0 me. per 100 g. in $C_2$ horizon. That meant that 7.5 percent, 5.4 percent and 4.4 percent of the total exchange capacities of A, $C_1$ and $C_2$ horizons, respectively, were occupied by potassium. The actual quantities of exchangeable potassium present were 1520 pounds per acre in A, 1130 pounds per acre in $C_1$ and 780 pounds per acre in $C_2$ horizon. The surface layer was rich in this element as compared $C_1$ and $C_2$ layers.

The concentration of exchangeable sodium in Sarpy fine sandy loam was 0.13 me. per 100 g. of soil in A horizon, 0.14 me. per 100 g. in $C_1$ and 0.35 me. per 100 g. in $C_2$ horizons. The actual quantities present were 59.8, 64.5 and 161 pounds per acre in A, $C_1$ and $C_2$ horizons, respectively. It was in very low concentration. The expression "in traces" might be justified for this concentration. These quantities amounted to only 0.5 percent in A, 0.5 percent in $C_1$ and 1.2 percent of the exchange capacity in $C_2$ horizon.

The exchangeable hydrogen was 1.99 me. per 100 g. soil in A horizon, 2.18 me. per 100 g. of soil in $C_1$ and 0.02 me. per 100 g. of soil in $C_2$ horizon. This amounted to 7.8 percent, 8.1 percent and 0.8 percent of the exchange capacities of the A, $C_1$ and $C_2$ horizons, respectively.

Base saturation percent in the soil was 92.2 percent in A horizon, 90.7 percent in $C_1$ and 98.0 percent in $C_2$ horizon. The picture of the exchangeable cations as a whole was that calcium was the most abundant of the cations. The order of abundance in descending fashion was:

$$Ca > K > H > Mg. > Na$$

## Exchange Capacity

The study of Table 19 revealed that the total exchange capacity of each soil type in Ladysmith series is 29.7 me. per 100 g. of soil in silty clay loam of A horizon, 45.0 me. per 100 g. of soil in clay of B horizon and 48.7 me. per 100 g. in silty clay of C horizon. The exchange capacities due to clay minerals only was 23.4 me. per 100 g., 38.8 me. per 100 g. and 36.2 me. per 100 g. of soil in A, B, and C.horizons, respectively. The respective percentages of the total exchange capacities were 79, 86.2 and 74.3, respectively. This showed that about 80 percent of the total exchange capacity was due to mineral colloids and the remaining 20 percent was due to organic colloids in Ladysmith soil. The X-ray diffraction data showed that the mineral composition of the Ladysmith soil consisted of the following clay minerals;

1. Montmorillonite as the dominant clay mineral associated with Illite, Kaolinite and Montmorillonite interstratified with Illite.

The total cation exchange capacities in Geary series were 26.9 me. per 100 g. in A horizon, 30.3 me. per 100 g. in B horizon and 28.1 me. per 100 g. in C horizon. The exchange capacities due to clay minerals were 22.8 me. per 100 g. in A, 30.0 me. per 100 g. in B and 24.0 me.per 100 g. in C horizons. On the average, 90 percent of the exchange capacity in this soil series was the contribution of the clay minerals present. The remaining 10 percent was due to organic colloids. X-ray diffraction data indicated that Montmorillonite was the dominant clay mineral present followed by Illite, and Kaolinite as associated minerals.

The cation exchange capacities in Sarpy series were 25.5 me. per 100 g. of soil in A, 26.9 me. per 100 g. in $C_1$ and 22.8 me. per 100 g. in $C_2$ horizons. The exchange capacities due to minerals present in each zone were 16.3 me. per 100 g. 16.2 me. per 100 g. and 15.9 me. per 100 g.of soil in A, $C_1$ and $C_2$ horizons, respectively. On the average about 64 percent of the exchange capacities in this soil were due to the mineral colloids of the soil. The clay minerals present in this soil, as shown by X-ray diffraction, are Montmorillonite associated with Illite, Vermiculite and with little Kaolinite.

## SUMMARY AND CONCLUSIONS

Three Kansas soils were taken for fertility studies. The approach to the problem was of physico-chemical nature. The soils are Ladysmith, Geary and Sarpy.

On the basis of the mechanical analyses performed, the testural classifications of the soil types were determined. The A horizon of Ladysmith consisted of silty clay loam, B horizon clay and C horizon consisted of silty clay. Geary soil in top layer showed clay loam, in B horizon silty clay and C horizon silty clay loam. Sarpy soil analysed as fine sandy loam throughout the profile.

Water saturation percentages were determined. Ladysmith showed 45 percent, 67 percent and 58.7 percent in A, B, and C horizons, respectively. The 67 percent saturation found in B horizon was the highest of all the types. Water saturation percentage values in Geary soils were 41 percent, 47 percent and 45 percent in A, B, and C horizons, respectively. Sarpy soil showed 33 percent, 32 percent and 34 percent of water saturation in A, $C_1$ and $C_2$ horizons, respectively.

Organic matter contents were determined in all the soil types. Ladysmith contained 4.1 percent, 1.5 percent and 0.67 percent in A, B, and C horizons, respectively. Geary soil contained 3.75 percent, 1.74 percent and 0.98 percent in the respective A, B and C horizons, while Sarpy fine sandy loam analysed as 1.2 percent, 0.93 percent and 0.6 percent in A, $C_1$ and $C_2$ horizons, respectively.

Soil pH values were determined and recorded as 5.6, 7.2 and 8.2 in Ladysmith A, B and C horizons, respectively, 5.7, 5.2 and 6.4 in Geary A, B and C horizons, respectively and a pH value of 8.0 was observed in each of the horizons of the Sarpy fine sandy loam soils.

Exchangeable cations were determined and their activity in soil profile studied. Calcium was found to be the most abundant cation in each of the soil types studied. The decreasing order of abundance of the exchangeable cations in Ladysmith group was found to be as:

$$Ca > H > Mg > Na > K$$

similar order of abundance in Geary soil was:

$$Ca > Mg > K > H > Na$$

and in Sarpy soil the order of abundance was:

$$Ca > K > H > Mg > Na.$$

Ladysmith soil had 6.5 percent of exchangeable sodium in B and C horizons. The accumulation of cations in lower layers indicated leaching of A horizon of bases. Sarpy soils had little magnesium. This soil seemed to be deficient in magnesium content.

Cation exchange capacities of each soil types were determined. Ladysmith soil had 29.69 me. per 100 g. of soil in A horizon, 45.0 me. per 100 g. in B horizon and 48.71 me. per 100 g. in C horizon. Eighty percent of the cation exchange capacity was due to the mineral colloids and 20 percent was due to organic colloids.

Cation exchange capacity of Geary soil was 26.9 me. per 100 g. of soil in A, 30.3 me. per 100 g. in B and 28.1 me. per 100 g. of soil in C horizon. Ninety percent of this value was due to clay minerals and 10 percent due to organic matter.

In Sarpy soil cation exchange capacity was 25.5 me. per 100 g. in A horizon, 26.9 me. per 100 g. in $C_1$ and 22.8 me. per 100 g. in $C_2$ horizons. Clay minerals contributed 64 percent and organic matter 36 percent of the total cation exchange capacity.

Clay mineral species were ascertained in these soils by using the X-ray diffraction technique. The clay minerals noticed in all these three soil series were;

Montmorillonite as a dominant mineral associated with Illite, Vermiculite and little Kaolinite.

## ACKNOWLEDGMENT

The author wishes to express his appreciation to his major professor, Dr. Floyd W. Smith, for his keen interest and able guidance in conducting this research problem and in the preparation of this thesis.

The author also expresses his gratitude to Dr. Roscoe Ellis and Dr. O. W. Bidwell for their assistance and able guidance in carrying out this research.

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# FERTILITY STUDIES OF THREE KANSAS SOIL SERIES
# i.e. LADYSMITH, GEARY AND SARPY WITH SPECIAL REFERENCE TO CATION EXCHANGE AND CLAY MINERALS.

by

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Hyderabad, India, 1949

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AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1959

Cation exchange is one of the most important phenomena in the field of soil fertility. This is the reaction through which nutrient cations are made available for plant use. That is why it is considered to be the second most important chemical phenomenon in nature, superceded only by photosynthetic activity.

Fertility studies of this type were made on three Kansas soil series: Ladysmith, Geary and Sarpy. Exchangeable cations throughout the profile were studied. In order to evaluate the soils under study, their mechanical analyses and organic matter contents were determined. Ladysmith soil was found to be of silty clay loam in the surface layer, clay in B horizon and silty clay in C horizon. Geary soil had clay loam in surface layer, silty clay in B horizon and silty clay loam in C horizon. The Sarpy soil consisted of fine sandy loam type throughout the profile.

Organic matter contents found in the top layers of these three soil series were 4.1 percent in Ladysmith silty clay loam, 3.75 percent in Geary clay loam and 1.2 percent in Sarpy fine sandy loam (cultivated).

Water saturation percentages were determined. Ladysmith had the highest value as 67 percent and the Sarpy the lowest 32 percent, while Geary had an intermediate value of 45 percent. These values were taken as indications of the corresponding water holding capacities of soils. Saturation extracts were obtained and analyzed for water soluble cations. Calcium and magnesium were not found in these. Potassium and sodium were present in small amounts. Soil pH was determined. Ladysmith had values of 5.6, 7.2 and 8.2 in its A, B and C horizons, respectively. Geary showed 5.7, 5.2, and 6.4 in its A, B, and C horizons, respectively. Sarpy had a pH value of 8.0 in each horizon.

Exchangeable cations were determined in each soil. Calcium was the most abundant exchangeable ion in each. Ladysmith showed evidence of leaching of cations from top layer to lower layers. Exchangeable Na occupied about 6.5 percent of the exchange capacity in the B and C horizons of this soil. The relative abundance of ions in decreasing order in Ladysmith was found to be:

$\mathrm{Ca > H > Mg > Na > K}$

In Geary: $\mathrm{Ca > Mg > K > H > Na}$

and in Sarpy: $\mathrm{Ca > K > H > Mg > Na}$.

Sarpy soil was very low in exchangeable magnesium and seemed to be deficient in that element.

Cation exchange capacities of these soils were determined. Ladysmith had a value of 29.67 me. per 100 g. of soil in A horizon; 45.0 me. in B and 48.1 me. in C horizon. Eighty percent of the exchange capacity was found to be due to mineral colloids and 20 percent due to the organic matter. Geary had cation exchange capacities of 26.9, 30.3, and 28.1 me. per 100 g. of soil in its A, B and C horizons, respectively. In this 90 percent of the total exchange capacity was due to the mineral colloids and 10 percent due to organic matter. Sarpy had cation exchange capacities of 25.5 me. 26.9 me. and 22.8 me. per 100 g. of soil in its A, $C_1$ and $C_2$ horizons, respectively. Sixty-four percent of the total cation exchange capacity was contributed by the mineral colloids and 36 percent by organic matter.

Clay mineral species were identified by using the X-ray diffraction technique in each soil series. Each of the three series, Ladysmith, Geary and Sarpy had Montmorillonite as a dominant clay mineral, associated with Illite, and small amount Kaolinite.